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EFFECTIVE SURFACE DRIVING FORCE CAUSING LIQUID TO SPREAD ON SOLID SURFACES

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Measurements of the dynamic and equilibrium contact angles of a sessile drop on solid surfaces has been used as a method to study wetting behaviour[1,2]. When a small sessile drop spreads on a flat solid surface, the resultant of the surface forces can be conceived as the main driving force that causes spreading. The rate of wetting can be considered to be represented also by the increase in the liquid–solid interfacial contact area.

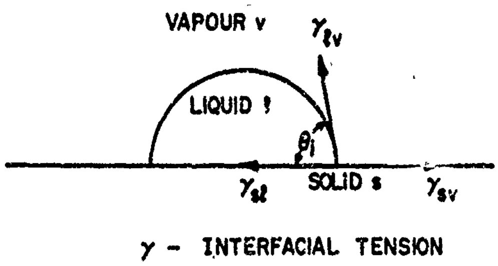

Fig. 1. Surface forces acting on the three-phase boundary of a sessile drop.

The main driving force that causes spreading is then, with reference to fig. 1,

$$F = \gamma_{sv} - \gamma_{sl} - \gamma_{lv} \cos \theta_l . \tag{1}$$

At equilibrium when spreading ceases, $F = 0$ and

$$\gamma_{sv} - \gamma_{sl} = \gamma_{lv} \cos \theta_e , \tag{2}$$

which is known as Young's equation where θ_e is the contact angle at equilibrium. (Usually θ_e can be estimated by θ_∞, the contact angle at a prolonged period of time under constant experimental conditions.) Substituting eq. (2) into eq. (1) yields

$$F = \gamma_{lv} (\cos \theta_e - \cos \theta_l) . \tag{3}$$

Now we define F in eq. (3) as the effective surface driving force for spreading, and consider the time rate of increase in the liquid–solid contact area,

$\mathrm{d}A/\mathrm{d}t$, to be directly related to this effective driving force, i.e.,

$$\mathrm{d}A/\mathrm{d}t = k\gamma_{\mathrm{lv}}\,(\cos\theta_{\mathrm{e}} - \cos\theta_{\mathrm{i}}), \tag{4}$$

or

$$\mathrm{d}A/\mathrm{d}t = k\gamma_{\mathrm{lv}}\cos\theta_{\mathrm{e}} - k\gamma_{\mathrm{lv}}\cos\theta_{\mathrm{i}}, \tag{5}$$

where k is a constant characteristic of a given set of experimental conditions such as temperature and drop volume, and of a given adhesive–adherend pair.

We have collected some preliminary results of a polystyrene melt (mol. wt. 4000, $\bar{M}_{\mathrm{w}}/\bar{M}_{\mathrm{n}}$ 1.06, Pressure Chemical Co.) spreading on a clean glass slide at 110 °C by a method which has been outlined in a previous communication[3]). When $\mathrm{d}A/\mathrm{d}t$ values are plotted against $\gamma_{\mathrm{lv}}\cos\theta_{\mathrm{i}}$ according to eq. (5), a linear relationship has been obtained. The value of θ_{e} calculated from the intercept at the $\mathrm{d}A/\mathrm{d}t$ axis yields a value of 41°25′, in close agreement with the measured θ_{∞} value of 43° after more than 50 min. Taking θ_{e} as 41°25′, a plot of eq. (4) again yields a straight line going through the zero-origin with an absolute numerical value of the slope identical to that obtained from eq. (5).

It has been theoretically predicted by Yin[4]) that the rate of spreading, $\mathrm{d}A/\mathrm{d}t$, is inversely proportional to the melt viscosity η and directly proportional to the one-third power of the drop volume V_0. Since η and V_0 at a constant temperature and pressure remain practically unchanged for viscous liquids of very low vapour pressure, it is conceivable that the value of k may be related to η and V_0. Search for such a relation, or its non-existence, is now under investigation in this laboratory.

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